ATRC
ARIZONA TRANSPORTATION RESEARCH CENTER

RESEARCH NOTES:

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ARIZONA INTELLIGENT VEHICLE RESEARCH PROGRAM – PHASE TWO: 2000 - 2001

Phase Two was the third year of ongoing research into vehicle and infrastructure-based Intelligent Transportation Systems technology (ITS) by ADOT (the Arizona Department of Transportation). Phase Two of this vehicle research ran from early 2000 through the 2000-2001 winter season, to the spring of 2001.

ADOT's Phase One research (1997 to 2000) explored numerous ITS concepts as potential solutions for urban and rural highway congestion problems. Arizona soon decided that the best near-term potential use of these technologies was to improve the safety and efficiency of winter maintenance.

In the first phase, the Arizona Transportation Research Center (ATRC) developed a winter maintenance research partnership with Caltrans (California Department of Transportation). Their prototype vehicle guidance system, on a Caltrans plow truck, was tested in Arizona in the winters of 1998–99 and 1999-2000. ADOT soon recognized the need for full-winter, long-term testing of driver-assistance systems on an Arizona snowplow.

One defining goal of this Phase Two research was the search for a new advanced snowplow system that ADOT could acquire for long-term testing. In early 2001, the ATRC reached an agreement with the 3M Company to purchase and install their Lane Awareness System package on an ADOT snowplow, with five miles of 3M tape to guide the vehicle.

Another new factor in the Phase Two research was the need for formal, unbiased analysis of training and evaluations for both the 3M and Caltrans driver-assistance concepts. Northern Arizona University in Flagstaff joined the project to monitor the training and testing, and to provide results and recommendations.

Phase Two of the project faced a number of setbacks during the 2000-2001 winter, but the project team developed creative solutions and pushed ahead. Equipment tests and training proceeded at Flagstaff with both systems. The two Advanced Snowplows were deployed in plowing operations at one or the other test site for nearly the entire winter. As a result, Phase Two was very productive. In particular, Arizona developed the first test program in the West with dedicated real-world high-altitude test sites for both the Caltrans and the 3M guidance systems, just 30 miles apart.

The Crucial Year: Winter 2000-2001

In this third project year, ATRC and the core of sponsoring ADOT Districts committed to procure and install a complete array of Advanced Snowplow equipment on an ADOT plow truck. This initiative would give Arizona its own local testing and training facility for the full extent of the winter, and in years to come as well. It would provide full-winter evaluations in Arizona conditions, and give the plow operators more long-term experience and confidence with each storm that occurred.

ADOT's first plan was to acquire a Caltrans system, using the ASP magnet-guided concept. This was not feasible, and so ADOT's Advanced Snowplow was equipped with the off-the-shelf commercial 3M Lane Awareness System. Other key AZ-ASP components were the Eaton VORAD EVT-300 Collision Warning Radar, as well as the GreyLink 1000 Automatic Vehicle Location system.

Partnering with 3M in this venture required ADOT to install magnetic striping tape in the roadway, creating a continuous low-strength magnetic signal for the snowplow's sensors. The test site would be was on US 89, ten miles northeast of Flagstaff in the Sunset Crater area. As part of a construction job, five miles of tape were installed between the layers of asphalt. Placing 3M's tape on the centerline of the two northbound lanes created ten lane-miles of magnetic-guidance infrastructure at this site.

The partnership with Caltrans was not affected by the decision to acquire the 3M lanekeeping system, and plans were made for a third season of training and operational plow tests with the Caltrans ASP in February. Arizona at this point had developed two complete infrastructure sites, with the Caltrans magnets and with 3M magnetic tape, for a total of 16 lane-miles. Training would be done on both systems, and the ADOT-3M plow would be used in the field all winter long. During the February '01 tests, ADOT would be able to assign two Advanced Snowplows to training and plowing operations on two mountain roadways just 30 miles apart.

Circumstances and Realities

Looking back at the positive factors from this third year of the project, it was an excellent winter for testing snowplows. The winter of 2000-2001 was ten percent above average in moisture for northern Arizona, based on the figures for the Flagstaff region, and 125 inches of snow were recorded. However, a series of major project issues arose, most of which could not have been predicted and could not be mitigated. As a result, Phase Two was unable to develop a full set of data on either snowplow, for the training program or for the operational evaluation.

Briefly reviewing the obstacles that arose, perhaps the greatest single issue was the temporary construction striping on the new 3M test lane at Sunset Crater. The roadway was carrying two-way traffic through the winter, and the striping did not match up with the alignment of the embedded 3M magnetic tape.

Another obvious problem for the US 89 test program and the new ADOT research plow was 3M's decision in December to withdraw from the snowplow guidance market. Despite their excellent continuing technical support, the 3M system was no longer a viable option for wider deployment.

The ADOT snowplow carried other IV systems for evaluation., but the failure of the forward collision warning radar, and its repair issues, meant that the entire winter passed without the ability to test and evaluate this critical vehicle safety system. It should be noted that the blind-side radar component did not fail.

Similarly, the AVL system was functional in its first year of deployment, but major issues of cellular coverage and cell service traffic loads were definite problems. Considering the difficulties in contacting the test vehicles, and the limited time for ADOT's operations staff to train and become proficient, the AVL system's tracking abilities were proven, but its level of success was quite limited.

When February arrived, and with it the Caltrans plow for training and testing, the schedule was set back by eight days of systems troubleshooting with California's own collision warning radar system as the primary issue. While a great deal was still accomplished at the test site on US 180, the end date of the Caltrans ASP loan schedule was firmly fixed, and ADOT was able to effectively utilize the snowplow for only a few weeks.

Phase Two Results

ADOT achieved some very significant results in Phase Two, the critical third year of the project. While beset by unexpected problems, the goals of training and operations at two mountain snowplow test sites were achieved.

Approximately 25 snowplow operators from eight maintenance camps in three ADOT Districts were trained on one or both of the advanced snowplows. Seven Team Leader Trainers took part, to varying degrees, and at least four of these operators were able to use the two Advanced Snowplows during regular plowing operations during significant winter storms over several months in 2000-2001.

Records show that the two snowplows accumulated nearly 3,000 miles of day and night plowing on their assigned routes on US 89 and US 180, in a dozen winter storms and many more call-outs. The ADOT plow was driven nearly 7000 miles over the winter, without damage or new failures of its operating IV systems. The Caltrans snowplow actually recorded more than 60 percent of its Arizona mileage in plowing operations during its few weeks of activity.

At both sites, the 3M or Caltrans magnetic infrastructure media was installed at the one most critical segment of each plow route. The Team Leader drivers frequently commented in their activity reports and in the surveys that the systems improved their confidence and helped them stay on track in their lane, during poor visibility and with heavy snow on the roadway.

The determination of the real cost of the systems to ADOT is somewhat complex. While 3M enabled the project to go forward by sharing part of the cost of the vehicle system and the five miles of tape, the Flagstaff District and the ATRC had other budget concerns with prime and sub-contractor costs to install it.

The 3M Lane Awareness System as installed on US 89 was valued at $14,500 for the truck equipment and $130,000 for five miles of tape. While some costs were shared, other contract costs were added. The value of the 3M tape infrastructure installed on the road centerline position, with two lane-miles covered with each mile of tape, therefore approximated $13,000 per lane mile. This figure compares to the $17,500 cost of the Caltrans magnets installed by ADOT, as noted in ATRC's Phase One project report. That cost, however, is based on ADOT's low wages and other local participation, such as equipment loans and other resources, and it is without any profit margins or other fee elements.

The NAU evaluation program focused first on operator-trainee surveys, but did not find any measurable ranking differences between 3M and Caltrans results. A number of valid comments, however, were noted. The main NAU effort was to survey ADOT managers for their views on advanced snowplow systems, and the extent of ADOT's need for them. The survey drew 69 responses, with a range of viable costs between $5,000 and $11,000 per lane mile. The survey also showed that ASP systems may benefit 1,000 to 3,000 lane miles.

The key results of this project in the 2000-2001 winter season are twofold. ADOT completed a second independent test site, and maintained its long-standing successful partnership with Caltrans. Despite setbacks and constraints, ADOT's Flagstaff District carried out extensive training and plowing, keeping key Arizona highways open with advanced snowplow technology. With all systems fully operational, more could have been achieved.

The results of the ADOT evaluation program were also significant. A neutral third party, Northern Arizona University, conducted extensive surveys and interviews with all levels of project stakeholders. The NAU team also collaborated effectively with evaluation teams From California and 3M / U of Iowa, enabling more refinements to the survey tools. With a larger sample size, more consistent training schedules, and all vehicle systems operational, more could have been achieved.

It is necessary to state here that despite the benefits to ADOT's snowplow operators and to the public, costs will always be an obstacle to deployment. For a rural state such as Arizona, these roadway infrastructures and vehicle systems may be practical only in the most critical locations of the state. The regional terrain will also determine what type of system is most appropriate, and offers the most value.

Recommendations

Based on the achievements of this project in Phase Two, the ATRC strongly supports

further research efforts in the coming winter of 2001-2002. It is clear that much more can be gained from this research program in the coming winters, when both the test site and the IV system problems have been resolved. The key recommendations developed from the Phase Two research program are:

- Calibrate and commission the 3M Lane Awareness system on US 89 as soon as construction ends and the permanent northbound lane striping is in place. Maintain a close working relationship with 3M for future support to the deployment, at ADOT cost.

- Repair the Eaton VORAD EVT-300 collision warning radar or replace it with another suitable system. If possible, evaluate the SmartCruise feature during the summer season.

- Continue the Caltrans partnership on US 180. Request full vehicle systems servicing prior to shipment to Arizona next winter. Request Arizona data collection on-board, as the vehicle is equipped to do. Based on driver comments, suggest Caltrans deploy the 3M vibrating seat.

- Resolve phone line and modem issues with the GreyLink AVL system. Seek additional training materials and classes for ADOT staff. Renew the software maintenance agreement.

- Extend the evaluation agreement with Northern Arizona University. Seek additional funding to enable a higher level of effort for NAU in the field, and in final data analysis and reporting. Refine the key studies, such as deployment estimates by management, from Phase One.

- Upgrade existing equipment and pursue new systems and concepts as the TAC may direct, with available resources. One issue from the stakeholder surveys is improved visibility. ATRC should study night vision systems, other vehicle radars, improved displays and warnings, etc.

- Expand the training and evaluation program at ADOT's two advanced snowplow test sites, to involve more maintenance personnel and other stakeholders from other parts of Arizona.

- Ensure that training is consistent for all generations of operators. The training should emphasize the unique aspects of each system design, and the non-standardized hierarchies of warnings which vary for each proprietary system (lights, chimes, vibrators and/or displays).

ADOT's Advanced Snowplow Summary

This advanced snowplow systems research program offers very significant benefits to ADOT and the public, in both safety and efficiency. The one principal goal of this project is to support Arizona's snowplow operators.

By improving the ability of the plow truck to keep moving in poor visibility, and to identify obstacles or hazards in the roadway, the risk of a collision from ahead or being struck from the rear will be lessened. By better monitoring of snowplow locations, materials usage, and plowing progress, supervisors can better manage the regional effort to clear the roadways, and can also respond much more quickly in situations that affect snowplow operator safety.

With further stakeholder and vendor support, ATRC expects that a future Phase Three, with all systems fully functional, will resolve the key issues about the potential of these IV technologies for rural states such as Arizona.

Note: The full report on this project, *Arizona Intelligent Vehicle Research Program – Phase Two: 2000-2001*, by Stephen Owen, PE, of the Arizona Transportation Research Center (Arizona Department of Transportation, Report FHWA-AZ-02-473(2), dated May 2002) may be obtained by faxing a request to 602-712-3400, or from the ATRC Publications web link at: www.dot.state.az.us/ABOUT/atrc/Index.htm.